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Crust and Uppermost Mantle Structure Beneath Southern Africa Based on First *P*-Wave Travel Times from Seismograms Generated by Local, Regional and Mining-Induced Earthquakes

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1. Abstract

Three-dimensional seismic wavespeed structure of the crust and uppermost mantle in southern Africa was determined by tomographic inversion of absolute arrivaltimes of first *P*-waves picked manually from seismograms generated by tectonic earthquakes and mining-induced tremors recorded at local and regional distances by 82 broadband stations of the 1997–1999 Southern Africa Broadband Seismic Experiment, supplemented by 3 IMS stations located in the study area. The data used in the inversion comprised 496 well-located seismic events and more than 1500 P-wave times. The geotomograms were determined by applying a tomography method in which traveltimes and raypaths are calculated rapidly and accurately by a 3-D raytracer, and the linearized iterative inversion utilizes the conjugate gradient-type LSQR algorithm. The assumed seed model is a regional average 1-D velocity model taken from previous seismic studies of lithosphere beneath southern Africa. Checkerboard resolution test was performed to confirm the reliability of the main features in the tomographic images. The tomographic images show patterns of heterogeneity in the wavespeed structure below the study area. The velocity anomalies reflect a superposition of various effects including changes in composition and thermal structure as well as other perturbations imprinted during the complex evolution history of the southern Africa region.

2. Introduction

The present study focuses on determining *P*-wave tomograms of the crust and uppermost mantle structure beneath the Kalahari craton and adjacent mobile belts. The input *P*-wave arrivaltimes are based on natural and mining-induced earthquakes recorded at local and regional distances by the 1997-1999 southern Africa broadband seismic network of the Kaapvaal Craton Project (Carlson *et al.,* 1996, 2000; James *et al.,* 2001; James and Fouch, 2002). The investigation of the seismic structure of the lithosphere in southern Africa is motivated partly by the need to map seismic wavespeed variations in the subcontinent to (i) guide area selection for mineral exploration ventures, (ii) provide additional information for understanding the structure of the earth's crust-mantle system and the origin, bulk composition, modification, and preservation of continents on earth, and (ii) improve our knowledge of the relationship between velocity anomalies and seismicity to contribute in the development of seismic hazard assessment for minimization of property damage, loss of human life, and social and economic disruption due to the inevitable occurrence of earthquakes in the region.

3. Location and tectonic setting

The study area (**Figure 3.1**) is mostly underlain by the Archean rocks of the Kaapvaal and Zimbabwe cratons, both of which constitute the Kalahari craton (**Figure 3.2**). Prior to the Mesozoic fragmentation of Gondwanaland, southern Africa formed a part of the Gondwana supercontinent, which amalgamated the remainder of the continent of Africa as well as Antarctica, Australia, India, Madagascar and South America (Tankard *et al.,* 1982; Anhaeusser, 1990).

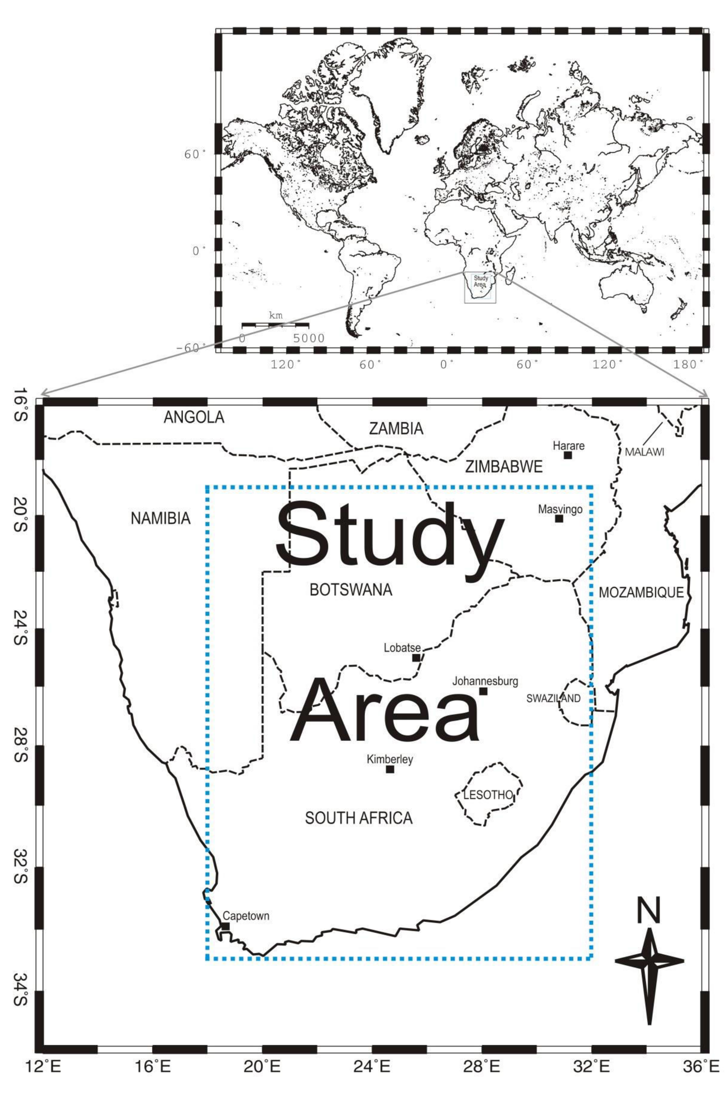

Figure 3.1: Location of the study area in southern Africa.

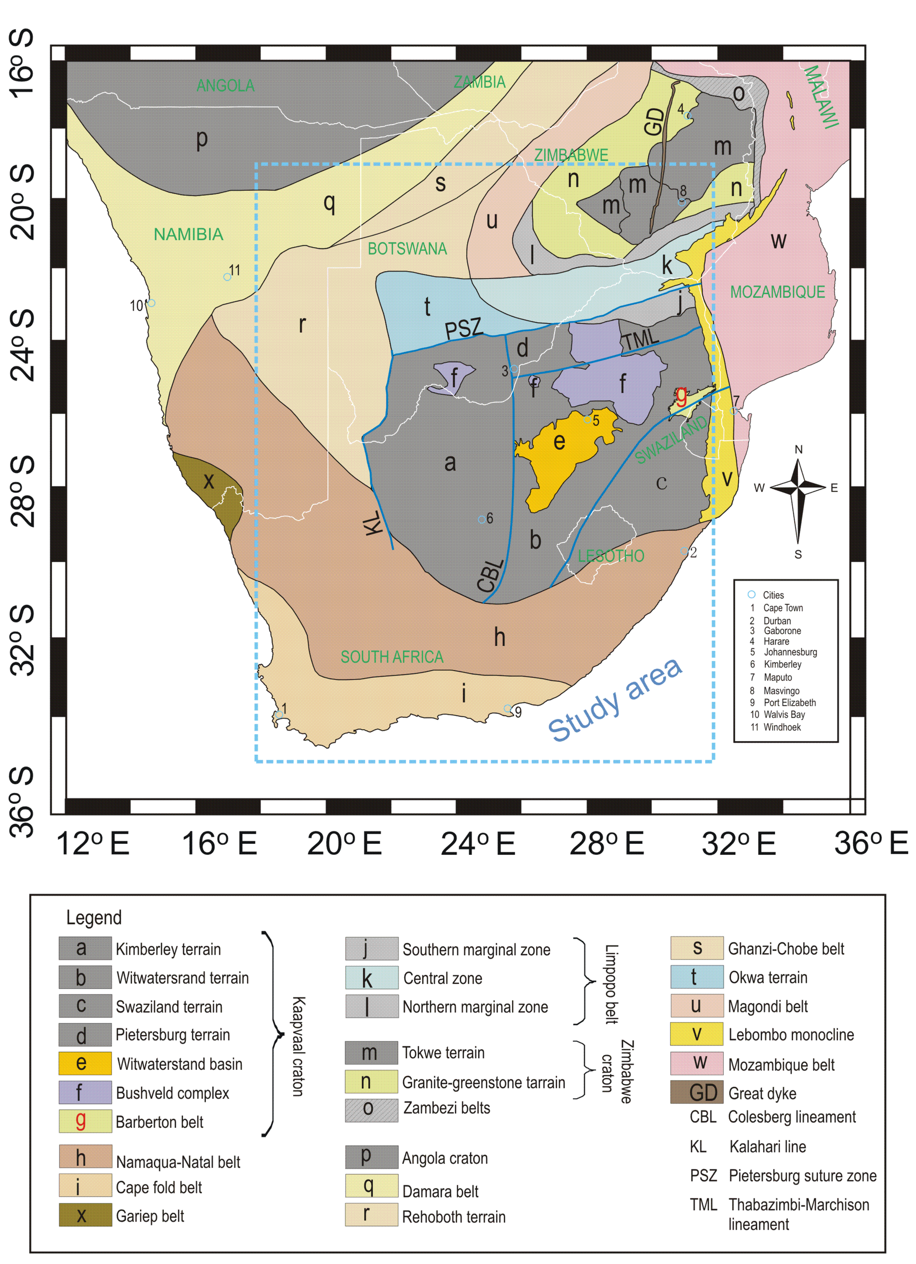

Figure 3.2.: An outline of major crustal blocks constituting the sub-continent (After Durrheim and Green, 1992; Carlson *et al.,* 1996, 2000; James *et al.,* 2001; Priestley *et al.*, 2006; Begg *et al.*, 2009)

4. Method and procedure

The tomography method and computer program TOMOG3D developed by Zhao (1991) and subsequently improved by Zhao *et al.* (1992, 1994) were used in the present study to carry out the 3D tomographic inversion for 3D *P*-wave velocity structure. In this method, a 3D ray tracing technique combines the pseudo-bending algorithm (Um and Thurber, 1987) and Snell's law. This 3D ray tracer can deal with the model containing complex velocity discontinuities. A detailed description of the Zhao inversion scheme is provided by Zhao et al. (1992), Zhao and Lei (2004), and Wagner *et al*., 2009.

5. Data and Results

We used high-quality seismograms recorded by the 3C broadband stations of the Kaapvaal seismic network (Carlson *et al.*, 1996; James *et al.,* 2001). The waveforms used in the analysis were requested from the Integrated Research Institutions for Seismology (IRIS) Data Management Centre (DMC) in Seattle, USA (http://www.iris.edu/dms/dmc/). The reference seed model is from Wright et al. (2002).

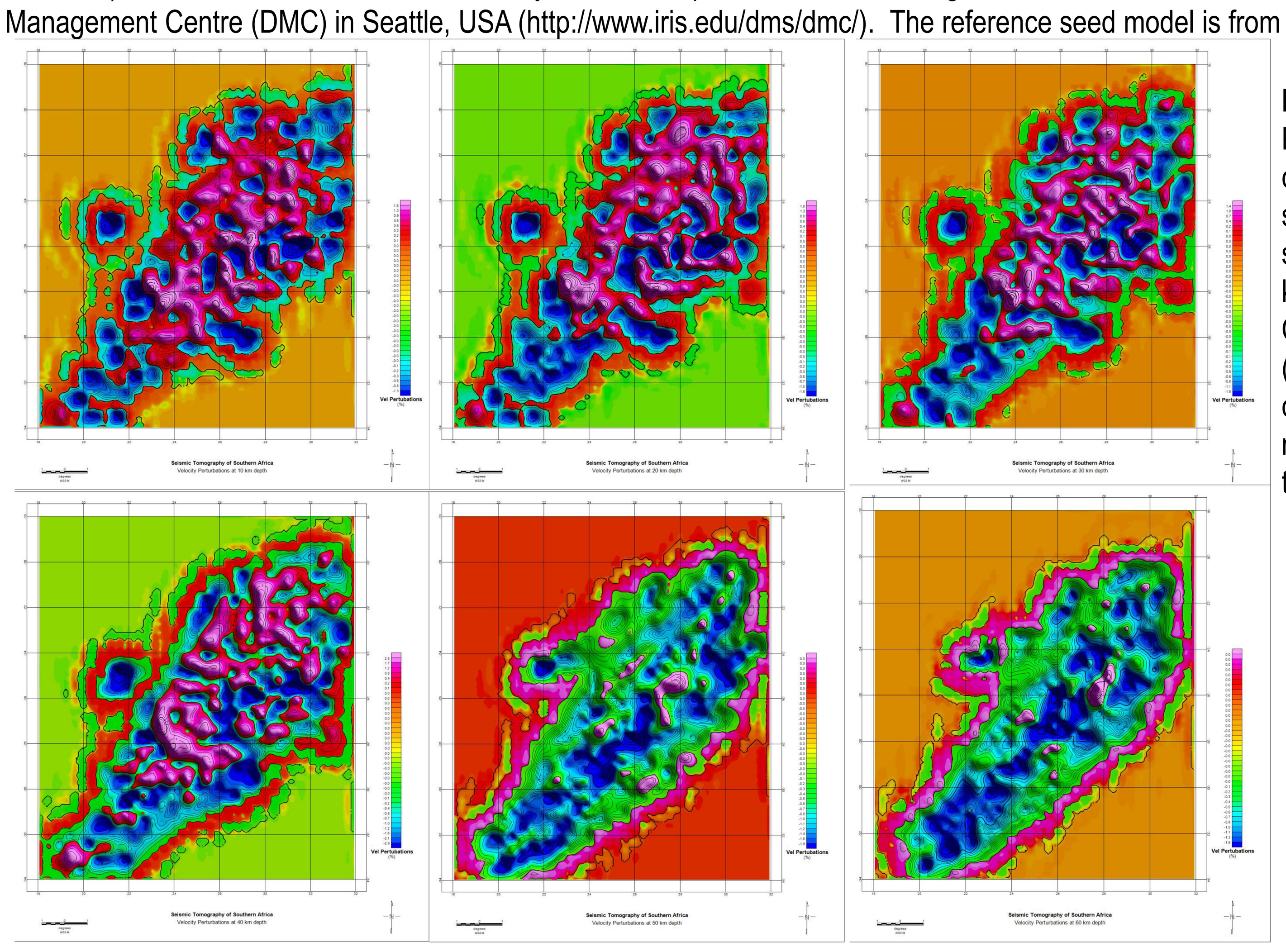

Figure 5.1: Contour-shaded P-wave toomograms of the crust-mantle system in southern Africa at depth slices of 10km down to 60 km (top and bottom rows). Checkerboard resolution test (CRT) was carried out to confirm the reliability of the main characters in the tomographic images.

6. Summary and Conclusions

In this study, three-dimensional *P*-wave tomography has been used to study the seismic wavespeed structure beneath the southern Africa subcontinent. The *P*-wave geotomograms in **Figure 5.1** show a pattern of broad heterogeneity in *P* wavespeed structure of the uppermost lithosphere below the study area. This seismic structure is the result of a superposition of various effects including changes in composition and thermal structure as well as other perturbations imprinted during the complex evolution history of the southern Africa region. A correlation of velocity heterogeneities with the accessible surface geology allows the results to be used further to study the correlations between surface geology and deep seismic anomaly patterns, and to infer possible mechanisms of crustal development in this region.

7. Acknowledgements

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8. References

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